Variability and Time Series Trend Analysis of Rainfall Over Krishna District of Andhra Pradesh: a Case Study

M. Rushi Kumar, M. Naveen, M. Sai Pravallika, Sanjeet Kumar

Abstract: Spatial-temporal variability of meteorological variables in the framework of changing climate is predominant. At the same time, if agriculture in those areas is depending on rainfall, then variables especially rainfall plays a vital role to assess climate-induced changes. Such types of studies will suggest feasible adaptation strategies of those particular areas. Spatial-temporal variability in rainfall has been focus of research over the past decade around the world due rainfed agriculture in developing country. Present study focus on rainfall variability and time series analysis of historical meteorological data of Krishna district, Andhra Pradesh, India using mann-kendall technique. Krishna district have importance in agriculture and it is upcoming urban area in Andhra Pradesh in terms of industrial and population growth. In the present study, the temporal variability is done for the annual time series of grid data over the period of 1977-2007 using Mann-Kendall technique. At the same time wet and dry day analysis was also performed, which shows increase in dry days and decrease in wet day over the area. With the results of this study, we can suggest some adaptation measures to increase the water availability of the region for the agriculture and population growth for the sustainable development of the region in the future with changing climate.

Index terms: Climate, Krishna, Parametric, Rainfall, Variability.

I. INTRODUCTION

Climate change is the most crucial and everyone's talk around the world and these changes bring a drastic change in everyone's life. This resulted drought, flood, cyclones, hurricanes and rise in temperatures. Human are unable to bear these changes and their effects, which occur due to changes of precipitation and temperature. Rainfall is the most important aspect for the Indian agricultural system. When a country like India requires unimaginable development along with many other aspects, rainfall plays a very important role. So, we need to analyze the rainfall data across the country to get the status, so that future rainfall criteria and its effects on various places can be determined. Presently there are many methods and techniques for the analysis of rainfall and temperature data with respect to temporal & spatial distribution.

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Statistically there are many techniques to analysis the rainfall and temperature data for their variations over an area. In statistics, trend analysis often refers to techniques for extracting an underlying pattern of behavior in a time series data, which would otherwise be partly or nearly completely hidden by noise. If the trend may be assumed to be linear, trend analysis can be undertaken with in a formal regression analysis, as described in trend estimation. If the trends produce other shape than linear, trend testing can be done by non-parametric methods, e.g. Mann-Kendall test, which is a version of Kendall rank correlation coefficient. Recent Mann-Kendall test shown its capacity to analysis the rainfall and temperature time series.

As some of the analyses shows that Kerala has positive trends in the winter total precipitation, extreme amount, and intensity, and negative trends in the frequency of the dry days. The state of Kerala has tendency to increase in autumn rainfall, while percent contribution from the extremes is significant in two gridded regions of interest [2]. Rainfall deficiency is relatively strong in the north-east, west-central and central north-east India, the regions of usual maximum monsoon rainfall, making the north India most vulnerable to summer droughts [2]. There is a significant decrease in south west monsoon rainfall while increase in post monsoon season. Cyclones developed during the post-monsoon season contribute significant amount of rainfall during the season [3]. Annual and seasonal trends of rainfall in the regions of Kerala are decreasing significantly is to be founded. A study of the seasonality index (SI) and located in one district within the northern region (Kasaragod) has seasonality index of over 1 which the distribution of monthly downfall during this district is generally attributed to one or two months [5]. Rainfall analysis for all 20 districts of Assam in various kinds like annual, monthly, daily, 24hr Max. rainfall and seasonal were calculated and trends are depicted. Various regions show decreasing trends and increasing trends of rainfall [1]. The applied math significance of the trend in monthly, seasonal and annual series was analysed using the non-parametric Mann-Kendall (MK) test. The present study has examined trends in the monthly, seasonal and annual rainfall on the meteorological subdivision scale, and for the whole of India [6].

The Mann-Kendall (MK) test was applied to quantify the significance and magnitude of trend respectively. The rank based non-parametric Mann-Kendall test has been commonly used to assess the significance of monotonic trends in hydro-meteorological time series and has been used in this study for the analysis of rainfall over the region of Krishna district. The Mann-Kendall test has two parameters that are of important for trend detection: the significance level, which indicates the trend's strength, and the slope estimate, which indicates the direction as well as the rate of change. Under the null hypothesis that there is no trend in the data, the distribution of S is then expected to have a mean of zero and a variance.

Krishna district is a territorial dominion within the Coastal Andhra region of the Indian state of Andhra Pradesh. Machilipatnam is the body headquarters and Vijayawada is that the most inhabited town within the district. As the temporary capital i.e., Vijayawada is situated in Krishna district, industrial area, urbanization and population increases a lot which makes the trend analysis of this area more important. It has a region of eight,727 km^2 (3,370 sq mi) and had a population of 45,29,009 as per 2011 census of India. It is delimited by West Godavari on the east, Bay of Bengal on the South, Guntur and Suryapet districts in the west and a portion of it also borders with the state of Telangana. The minimum and maximum Lat & long of Krishna district is as follows: 15.43° N, 17.1° N (Latitudes) & 80.00° E, 81.33 ° E (Longitudes)The objective of this study is:

1. To assess the historical changes in rainfall pattern over the Krishna district of Andhra Pradesh.

II. MATERIALS AND METHODS

The reliability and legitimacy of any research work depends largely on the accuracy of data sets with relevant information on study area and the methodology adopted. This chapter deals with the description of study area, data acquisition of various. Overall, the methodologies adopted, and data used in this work is described in this chapter

Study Area

Krishna district is a territorial dominion within the Coastal Andhra region of the Indian state of Andhra Pradesh. Machilipatnam is that the body headquarters and Vijayawada is that the most inhabited town within the district. It has a region of eight,727 $km2^2$(3,370 sq mi) and had a population of 45,29,009 as per 2011 census of India. It is delimited by West Godavari on the east, Bay of Bengal on the South, Guntur and Suryapet districts in the west and a portion of it also borders with the state of Telangana. It has a complete lineation of eighty eight kilometer (55 mi). The main hill varies of the district referred to as Kondapalli runs between Nandigama and Vijayawada with a length of regarding twenty four kilometer. The other smaller hill ranges area unit Jammalavoidurgam, Mogalrajapuram and Indrakiladri hills. Kolleru, is the large freshwater lake in India. It spans into 2 districts – Krishna and West Godavari. The minimum and maximum Lat & long of Krishna district is as follows: 15.43° N, 17.1° N (Latitudes) & 80.00° E, 81.33 ° E (Longitudes).

MAP

Fig. 1: Rain Gauge stations for the Gridded Region Named as KRISHNA 1,2,3,4

But the Rain gauge stations are present exactly at the same place where the boundary points of Krishna district are present. So, we preferred the near-by rain gauge stations as the control point where we can get the rainfall data exactly which covers the entire district. They are as follows: D) PY 155*795(K1), C) PY 155*805(K2), A) PY 175*805(K3), B) PY 175*815(K4).

III. METHODOLOGY

We collected the daily rainfall grid data from IMD Pune for a period of 30 years i.e., 1977 – 2007 respectively. Using the daily rainfall data, we calculated the average monthly rainfall, yearly precipitation, No. of dry days in these year and No. of wet days in these years respectively. We used one of the widely used non- parametric tests i.e., Mann – Kendall technique to get the trends for the daily rainfall data.

Trend Analysis of Historical Meteorology Data

Trends and changes in precipitation and temperature have been a focus of research over the past decade. In the present study, the spatial and temporal trend analysis of the annual and monthly time-series of a set of IMD grid data for precipitation and temperature across Krishna District, over the period of 1977–2007, has been performed. The Mann-Kendall (MK) test was applied to quantify the significance and magnitude of trend respectively. The rank based non-parametric Mann-Kendall test has been commonly used to assess the significance of monotonic trends in hydro-meteorological time series and has been used in this study for the analysis of rainfall and temperature over the region of Krishna district. The Mann-Kendall test statistic is given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

$$sgn(\theta) = \begin{cases} 1 & if\ \theta > 0 \\ 0 & if\ \theta = 0 \\ -1 & if\ \theta < 0 \end{cases} \quad (2)$$

Where, n is the data set record length; x_j and x_k are the sequential data values.

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The Mann-Kendall test has two parameters that are of important for trend detection: the significance level, which indicates the trend's strength, and the slope estimate, which indicates the direction as well as the rate of change. Under the null hypothesis that there is no trend in the data, the distribution of S is then expected to have a mean of zero and a variance of

$$var(S) = \frac{n(n-1)(2n+5)}{18} \quad (3)$$

and the normal Z-test statistic is calculated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & if\ S < 0 \end{cases} \quad (4)$$

The null hypothesis is rejected at significance level of α if $|Z|>Z_{(1-\alpha/2)}$. Here, $Z_{(1-\alpha/2)}$ is the value of the standard normal distribution with a probability of exceedance of α/2. A positive value of Z indicates an upward trend while a negative value represents a downward trend. Trend magnitude is estimate using a nonparametric median based slope method proposed by Sen (1968) and extend by Hirsch et al. (1982) as given below:

$$\beta = Median\left[\frac{X_j - X_k}{j-k}\right] \quad for\ all\ k < j \quad (5)$$

Where, 1<k<j<n. β is median of all possible combinations of pairs for the whole data set.

IV. RESULTS & DISCUSSION

The average monthly, yearly, No. of dry days and No. of wet days for the 30 years daily precipitation data collected from IMD Pune are shown in Table 1.

Table I: Monthly precipitation of the 4 different stations selected for the period of 30 years respectively

MONTH	K_1	K_2	K_3	K_4
January	12.2	13.7	7.87	6.15
February	9.6	10.2	9.4	9.9
March	10.8	10.9	13.1	8.26
April	16.5	12.6	32	27.2
May	58.1	62.4	29.3	49.8
June	54.3	78.8	149	149
July	108	145	306	281
August	92.3	146	3.1	283
September	124	161	178	179
October	183	210	131	29
November	130	162	30.6	27.2
December	12.9	32.2	5.64	6.46

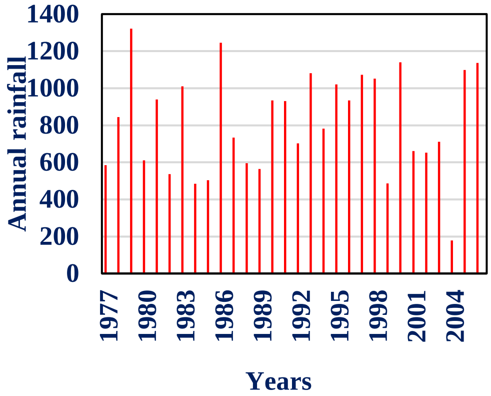

Fig. 2: Yearly precipitation of the K1 station selected for the period of 30 years.

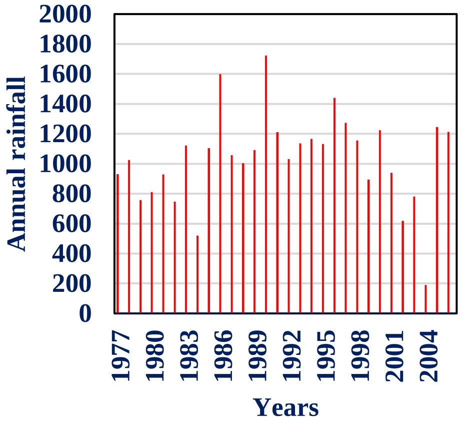

Fig. 3: Yearly precipitation of the K2 station selected for the period of 30 years.

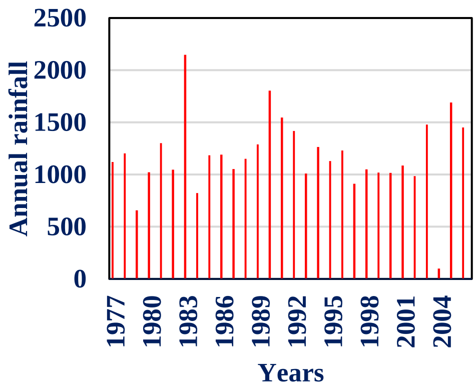

Fig 4: Yearly precipitation of the K3 station selected for the period of 30 years

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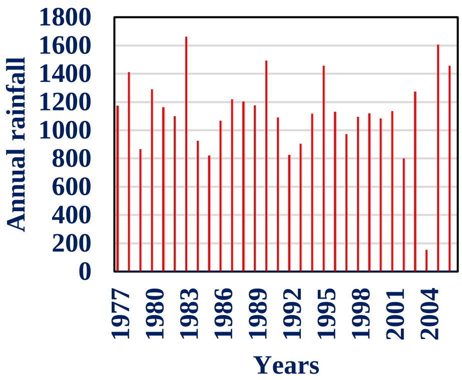

Fig. 5: Yearly precipitation of the K4 station selected for the period of 30 years

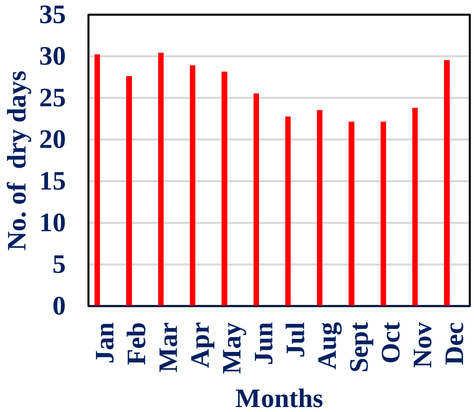

Fig. 6: Average number of dry days of K1station selected for the period of 30 years

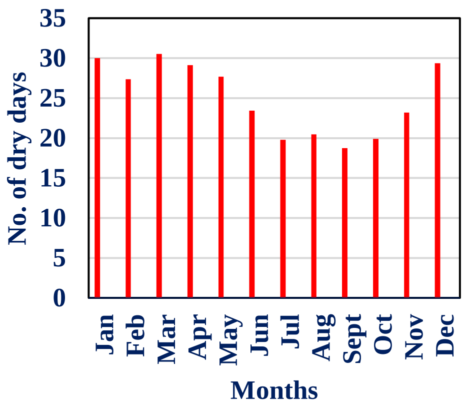

Fig. 7: Average number of dry days of K2station selected for the period of 30 years

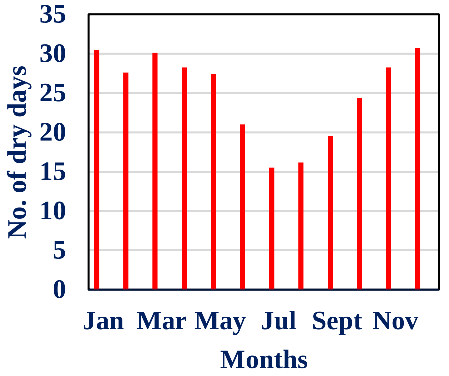

Fig. 8: Average number of dry days of K3 station selected for the period of 30 years

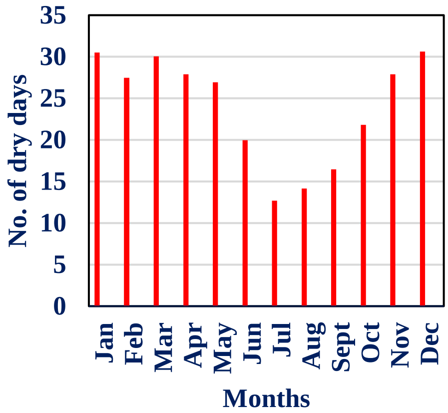

Fig. 9: Average number of dry days of K4 station selected for the period of 30 years

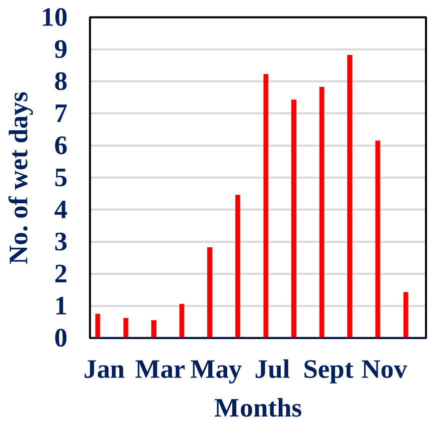

Fig. 10: Average number of wet days of K1station selected for the period of 30 years

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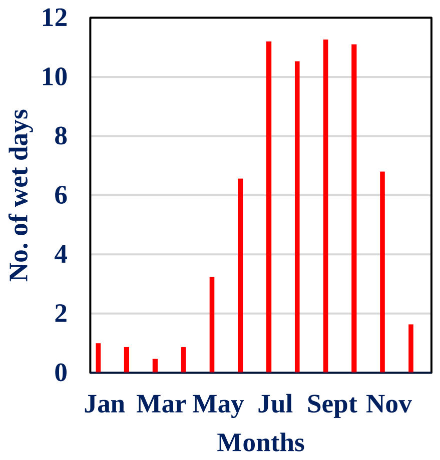

Fig. 11: Average number of wet days of K2 station selected for the period of 30 years

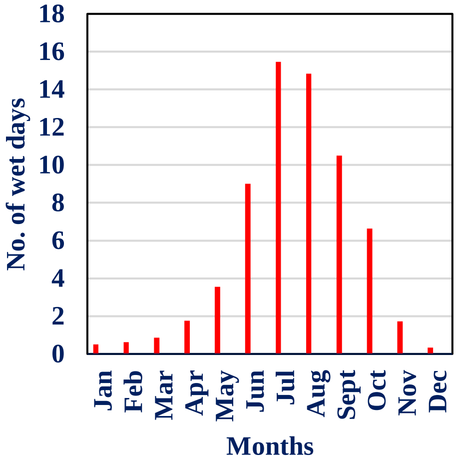

Fig. 12: Average number of wet days of K3 station selected for the period of 30 years

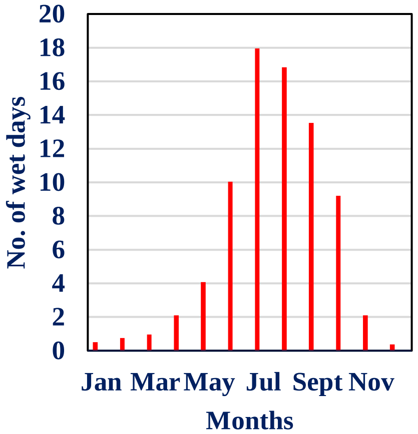

Fig. 13: Average number of wet days of K4 station selected for the period of 30 years

Summary of trend analysis for annual rainfall using Mann-Kendall nonparametric test. Table II shows the Results for annual trend analysis for rainfall

Table II: Results for annual trend analysis for rainfall

Grid	Annual rainfall		
	β	Z	P
KD1	-0.666	-0.095	
KD2	-2.140	-0.422	
KD3	3.184	0.640	
KD4	-5.866	-1.430	

NOTE: Z is statistics of Mann-Kendall test; β is the slope estimator.

Generally, a trend analysis gives an idea of how the climatic variables are changing with time from the mean state. In this study trend analysis was carried out using Mann-Kendall non-parametric test, to know the existence of trend in the data series (rainfall, minimum and maximum temperature during the period 1977-2006) of four IMD grids (KD1, KD2, KD3, KD4) covering the Krishna district.

The monthly average precipitation at the four stations in Krishna district reveals that the monhs of july, august, septmber& october received the maximum rainfall. If you had considered this analysis for the seasonal basis result, then the monsoon season received the maximum rainfall of about 150cm – 250cm of rainfall for the period of 30 years (1977-2007). The pre-monsoon period i.e., april, may, june received a rainfall not more than 100cm on an average monthly basis. In addition to that post-monsoon season i.e., october, november received the best rainfall in all 4 stations of about 200cm. If the winter season analysis is considered , then months of december, january, febraury & march received less than 50cm which makes it the dry season as always. So, considering the results of these monthly average precipittion , the monsoon season received required amount of rainfall unlike the other seasons.

As the yearly precipitation for the period of 30 years i.e., 1977-2007 is considered then at station 1, good amount of rainfall for the priod of 1990-1998 & then for the year of 2005,2006 unlike the other yers which received a very less amount of rinfall compred to the former. If station 2 is taken into consideration the 1st decade i.e., 977-1986 received average of 1000cm rainfall, 2nd decade received more than 1200 cm rainfall & 3rd decade received an average of 1000 cm rainfall. At station 3, 1st decade received very less rainfall i.e., on an average of less than 1000 cm rainfall 2nd decade received good rainfall of above 1000 cm of rainfall and 3rd decade received on an average of 1000cm rainfall. Gladly station 3 received good amount of rainfall, if station 4 is taken care then, 1st decade received a minimum of 1200 cm rainfall as well as 2nd& 3rd decade respectively. As this yearly analysis is observed, all the years in all stations received certain amount of rainfall except the year 2004 which received a very less amount of rainfall & considered as th dry year of the 30 years period.

The analysis of dry days is observed, then at station 1, for 1st decade of 1977-1986, the months of january, febraury,

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march,april,may& december got the maximum number of dry days & other months got the average of 10-20 dry days, 2nd decade of 1987-1996 the similar pattern of dry days i.e., 15-20 days for months of july, june, august, september,october& november. The 3rd decade i.e., 1997-2006 also follow similar patter like that of 2nd decade. i.e., 1897-1996. For station 2, all the 3 decades i.e., 30 years of period (1977-2007) got the dry days on an average of 10-15 days for monsoon months of july,august & september, winter season remains dry as usual,with certain amount of rainfall moderately for pre-monsoon & post-monsoon seasons making

the dry days for 20 days on an average. At station 3, the monsoon months of july,august, september & october received the least number of dry days i.e., 5-15 days which makes the best rainfall receoved at these areas where station 3 is present. Thus giving the more amount of rainfall for that region. Statio 4, also shows that unlike station 1&2, monsoon season dry days are very low and thus helping to the more amount of rainfall. Here all other reasons almost get the dry days of 25-30, for monsoon season it ranges from 10-15 days in all the 3 decades period of 1977-2007 respectively.

As the analysis of wet days comes into picture, the things changed contradictively to the analysis of dry days for 30 years of period. The station 1 shows that for 3 decades july, september, august, october, even november received the more amount of rainfall i.e., the no. of wet days ranges from 12-18 days in all years. At station 2, for 2 decades i.e., 1977-1996, the wet days ranges from 14-18 days conastantly, but for the last decade i.e., 1997-2006 the wet days are a bit less thus showing less amount of rainfall when compared to the other decades. At station 3, nearly all 3 decades for the months of july, august, september, june got more no. of wet days which makes a very good monsoon season for the region thus helping for all rainfall related activities. The no. of wet days ranges from 20-25 days help a lot for the region. If station 4 results are considered, th no. of wet days are very less or almost zero for pre-monsoon, winter seasons. For all decades the months of july, august showed highest no. of wet days ranging from 10-20 days respectively. So, the no. of wet days brings a hope that monsoons are good at the station 1,3,4 but a little bit less at station 2. So, Krishna district received good amounts of rainfall in the monsoon as far as this analysis is concerned.

V. SUMMARY AND CONCLUSIONS

The analysis of the precipitation data collected for the period of 30 years at the 4 stations of Krishna district for yearly, monthly, No. of wet days & No. of dry days clearly shows that the monsoon season received a good amount of rainfall due to the south-west monsoon. The year of 2004 received very less amount of rainfall making the dry year of entire analysis period. Even the months of october, november received good rainfall for all years on an average shows that the Krishna district has a good effect by the north-east monsoon,thus paving way for the good establishment of all activities & development.

A case study of krishna district is selected for the trend analysis of meteorological data. It is one of the non-parametric tests i.e., Mann-Kendall technique is used extensively. The results are exclusively presented using the Matlab code. Results show the different kids of trends either increasing or decreasing. The graphs of average monthly,yearly, No. of wet days, No. of dry days are exhibited which gave the clear view of the effect of south-west & north-east monsoons over the Krishna district. This shows that for the monsoon season & even post-monsoon season, the amount of rainfall is good. This amount of good rainfall helps in the water resource management system i.e., the amount of water need to be supplied for irrigation, amount of water that to be stored for other purposes. Even the rainwater that can be transported to the places where there is a lack of water & requires helping hand for the agricultural purposes. In the future, we need to use the rainwater in such a way that every single drop of water is used in the righteous way for the healthy & prosperous development of state. We should be careful that the rainwater should be stored in an effective way& also the ground water table should be maintained at a possible height of using it properly. So, this trend analysis is useful in all way possible for the weather forecasting, thus by developing the human and environmental aspects.

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